



Australian Shipowners Association

**Assessment of Introduced Marine Pest
Risks Associated with Niche Areas in
Commercial Shipping**

Final Report

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Executive Summary

Marine pests are known to be introduced and translocated in a variety of ways including natural vectors, ballast water from commercial shipping, biofouling, aquaculture operations, aquarium imports, marine debris and ocean current movements.

Ballast water management has for some time been focus for marine pests issues associated with commercial ships. But the risks resulting from biofouling are not well understood. While it is well established that there exists a strong operational incentive for vessel owners to maintain smooth hulls free of fouling, anecdotal evidence suggests that there are areas of the hull, 'niche areas', where prevention of biofouling is difficult and not so critical to efficient operation.

It was the purpose of this project to address a gap in knowledge and, in a qualitative way, assess the marine pest risk associated with these niche areas. Importantly, the project also aimed to produce recommendations on how biofouling in these niche areas could be prevented, and the marine pest risk reduced.

Niche areas include such things as sea chests, bow thrusters and bow thruster tunnels, bilge keels, anodes, hull penetrations such as seawater intakes and discharges and grates, rudders, rudder stocks and docking support blocks.

Eight vessels were observed in dry dock in Australia and Singapore. Potential niche areas were inspected and samples of biofouling taken. Samples were then sorted and sent to specialists for identification.

Information was collected from vessel owners about the vessel routing, previous hull treatment and the operation of the various hull appendages observed. Paint manufacturers also provided information about various products and techniques available for niche area biofouling prevention.

The project confirmed that niche areas are likely to be more vulnerable to biofouling than the main hull for a combination of the following reasons:

- Reduced dry film thickness of antifouling paint on angular edges of grates and hull penetrations.
- Hull protrusions can disrupt the flow of water over the hull causing eddies and premature polishing of antifouling paint.
- High water turbulence and cavitation can prematurely polish antifouling paint and remove it from the hull surface.
- Mechanical damage can remove antifouling paint and leave the hull surface exposed to fouling.
- Antifouling paint does not polish at the required rate in areas of static water such as sea chests and behind anodes rendering it inactive.
- Some sea chests are not fitted with marine growth protection systems or they do not work in accordance with the manufacturers recommendations.

To address the biofouling risk in each of the niche areas recommendations were made including the use of different antifouling products with different polishing rates and composition in different areas around the hull and careful hull preparation and paint

application. It was recommended that angular bars be replaced with round bars to maintain antifouling paint dry film thickness and marine growth protection systems be operated to an effective level.

It was also found that it is likely that there will always be a risk of paint system failure for a variety of reasons and that a controlled approach to in-water cleaning under permit be investigated and in the first instance, the ANZECC Guidelines for In-Water Cleaning be reviewed.

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1 Introduction

Marine pests are known to be introduced and translocated in a variety of ways including natural vectors, ballast water from commercial shipping, biofouling, aquaculture operations, aquarium imports, marine debris and ocean current movements.

Voluntary codes of conduct and best practice management guidelines are being developed to address biofouling risks from a range of sectors. These codes and guidelines will provide management measures to prevent new marine pest introductions and control of established populations.

Sectors that have been addressed in relation to biofouling issues include domestic recreational vessels, commercial vessels, fishing vessels, aquaculture, the petroleum and gas sector and ports, marinas and slipways.

While significant resources have been invested into mitigation of the marine pest risks believed to be associated with ballast water, very little focus has been given to determining the marine pest risk associated with biofouling on commercial vessels and less still to the investigation of options available to the industry to mitigate any apparent risk.

Biofouling increases hull roughness and there is a strong incentive for vessel operators to minimise hull roughness in order to maintain operational efficiency. Antifouling paint is applied to the hulls of commercial vessels to prevent biofouling attachment. Technological advances in antifouling paint are such that if the correct product is applied in accordance with the manufacturer's recommendations, excellent results can be achieved with little or no biofouling attachment on the main hull.

There is anecdotal evidence, however, that suggests there are 'niche areas' on the underwater surface of the hull that are more vulnerable to fouling. 'Niche areas' include such things as sea chests, bow thrusters and tunnels, rudders, anodes bilge keels etc. The relative occurrence of biofouling in these areas was unknown, as was the marine pest risk arising from these areas.

The project in part addresses this gap in knowledge by systematically observing biofouling on eight commercial ships in dry dock.

The project also enabled the development of a guideline (Annex I) to provide options for managing and treating biofouling on commercial vessels that includes guidance on hulls, internal seawater systems and niche areas such as sea chests, sea intake grates, bow tunnels, anodes, transducers, docking support strips, propellers, rudders and shafts.

The guideline aims to ensure the risk of translocating and introducing a marine pest is minimised. It is critical that the marine pest issues associated with the industry are clearly understood and that practical and effective management solutions that build on existing industry actions are implemented.

2 The Project

2.1 *Project aims and outcomes*

To qualify the level of niche area fouling on commercial vessels and research potential management options with a view to reducing the risk of marine pest introduction and translocation, through the development and implementation of a set of guidelines to address niche area biofouling on commercial vessels.

The project will involve a targeted program of commercial vessel inspection at dry-dock, specimen collection and collaboration with appropriate research institutions in specimen identification and research into available technology and potential management options.

2.2 *Targeted dry-dock inspections and specimen collection*

Dry-dock inspections were chosen above in-water inspections for ease of sample collection and cost effectiveness. The following eight ships were inspected in dry dock:

- MV Spirit of Tasmania III, Forgacs-Cairncross Dockyard, Brisbane, 26 July 2005
- MT North West Snipe, Sembawang Shipyard, Singapore, 26&27 September 2005
- MV Endeavour River, Sembawang Shipyard, Singapore, 11&12 November 2005
- MT Petro Navigator, Tropical Reef Shipyard, Cairns, 23 January 2006
- MV Fitzroy River, Sembawang Shipyard, Singapore, 17 June 2006
- MT Petro Discoverer, Tropical Reef Shipyard, Cairns, 24 July 2006
- MT Basker Spirit, Sembawang Shipyard, Singapore, 25&26 August 2006
- MV Alltrans, Sembawang Shipyard, Singapore, 11&12 September 2006

Specimens of organisms collected were sorted and delivered to appropriate participating specialists for identification. Of particular interest was the presence or absence of tubeworms, barnacles, bivalve molluscs, and mobile crustaceans.

3 Hull Antifouling Systems

3.1 *Operational relevance*

The hulls of commercial trading ships must be clean and free of fouling to maintain operational efficiency. As the roughness of the hull increases, so does fuel consumption and engine wear, and the vessel is less likely to be able to maintain speed and meet tight schedule requirements. It follows therefore that hull maintenance and the prevention of biofouling growth is an important consideration in commercial ship operation.

To prevent biofouling growth ships' hulls are painted with antifouling paint. Biocidal antifouling paint prevents biofouling attachment by continuously releasing a biocide (most commonly copper compounds) from the coating surface, which either kills or deters the settling spores or larvae (Lewis, 2002). Fouling release antifouling coatings are based on silicone compounds and create a surface that minimizes the strength of adhesion of attaching organisms. Organisms are dislodged when vessel speeds of over 15 knots are reached or are easily removed when the hull surface is cleaned manually when speeds of 15 knots are not achievable.

There are various different antifouling paint products on the market with different characteristics relating to the methods and speed of biocide release and the effective paint life span. As such, antifouling paint efficacy is dependant on matching the product to the particular activity profile of the vessel and the required service time between dockings.

Further, paint efficacy is dependent on the integrity of the coating. De-lamination, flaking and peeling of the antifouling paint will occur as a result of undercoat defects (anticorrosive, tie coat) or when the antifouling coat has not been applied in direct accordance with the manufacturer's specifications or the hull surface has not been prepared correctly.

Even small coating defects provide opportunity for barnacles to settle, further compromising the integrity of the paint coating and encouraging the settlement of other organisms.

3.2 General Observations

Areas on the main hull that showed evidence of incidental mechanical damage to the paint coating also showed evidence of fouling growth. Mechanical damage can occur as a result of fender and berth impact, dropping and retraction of anchors, incidences during loading operations and collisions with debris while at sea.

There were also clear examples of hull zones that are routinely affected by operational impacts causing antifouling coating damage. Such coating damage can occur when vessels hull makes contact with silty sea floor causing abrasion and eventual removal of the paint coating. The abrasive or impact affect, while damaging the paint coating, also makes it difficult for fouling organisms to settle.

Patchy paint defects occurred high on the hull on the water line evidenced by sporadic barnacle settlement. This was most likely due to the varying conditions of these areas that cause drying and cracking of the antifouling paint as it is periodically both dry and underwater while the vessel is fully loaded or in ballast.

Barnacles overall were found to be most efficient at settling on the smallest paint defect, spreading and lifting paint coatings.

While sporadic and patchy paint defects on the hull surface due to mechanical damage and varying conditions were common, extensive failure of the antifouling paint system allowing extensive biofouling coverage over the main hull was rare.

3.3 Recommendation

Hulls should be painted with antifouling systems able to prevent biofouling between dockings. The system applied should take into account the planned docking period and the ship's speed and activity (nautical miles per month). The choice of paint and application specification to meet the requirement should be developed in consultation with the paint manufacturer or their technical representative.

Where antifouling paint is damaged as a result of grounding or mechanical impact in-water repair of the paint system should be considered if the area of damage is relatively minor. If damage is extensive the ship should be dry-docked for repair at the earliest opportunity.

4 Internal Seawater Systems

4.1 Operational relevance

Internal seawater systems on commercial trading vessels take in water from the ocean for the purpose of engine cooling, emergency fire fighting and ballast uptake and discharge. Piping for internal seawater systems can be extensive and their unrestricted operation, particularly for engine cooling is vital to the ongoing and efficient operation of a vessel.

Biofouling growth can be a particular operational problem when severe fouling occurs in internal sea water systems as it can restrict the water flow to critical engine cooling systems. The internal surfaces of sea water systems provide refuge settling habitat for biofouling species that have a pelagic larval life stage.

4.2 General observations

For reasons of practicality, internal seawater systems were not included in the field observations for this project. However, anecdotal evidence suggests that there is widespread use of marine growth protection systems. These systems dose seawater with chemical compounds (chlorine or copper) which destroys larvae at uptake. Where significant fouling occurs within internal seawater systems due to defective marine growth protection systems, engine overheating and premature wearing can occur.

4.3 Recommendations

Internal seawater systems prone to biofouling should be fitted with effective marine growth protection systems. Systems need to be regularly monitored to ensure effective biofouling control is maintained.

If seawater systems become fouled they should be treated with an approved product to kill fouling¹.

5 Sea Chests

5.1 Operational relevance

Sea chests are box like hull penetrations designed to reduce hull friction from, and maximise flow into seawater suction pipes for engine room cooling, ballast water operations and emergency fire fighting. Water flow within the sea chest is significantly lower than across the main hull surface, creating a relatively low flow refuge area (Taylor et. al. 2002).

As the water flow is much lower the antifouling paint used may have a biocide release rate that is much too low for such a low flow area, making the antifouling paint ineffective and sea chests particularly vulnerable to colonisation by biofouling species.

While the minimisation of sea chest biofouling is desirable from a ship maintenance point of view, the existence of biofouling on the internal surfaces of sea chests may not have a negative impact on ship operations as long as the flow of water through the sea chest is not impeded.

¹ See guidelines for the prevention of biofouling in internal seawater systems

The edges of hull penetrations such as sea chests are often angular. When painted with antifouling paint, the high surface tension created from these angles reduces the dry film thickness of the antifouling paint in these areas, reducing the effective life of the paint.

Sea chest openings are covered by grates as a primary means of filtering out large items of debris. Sea chest grates can be flush with the hull surface, indented or protruding from the ships' hull. Sea chest grates generally use angular bars, increasing surface tension when painted, reducing the paint dry film thickness on the bar edges and reducing the effective life of the antifouling paint.

Sea chest grates are highly susceptible to biofouling colonisation as a result, and the protruding and indented sea chest grate designs increase the potentially vulnerable areas by creating more angular edges.

Biofouling around the edges of hull penetrations such as sea chests and sea chest grates can interfere with the water flow over the hull, causing friction and may result in reduced operational efficiency and increased fuel consumption.

Sea chest grates that are blocked with biofouling growth can cause operational problems by restricting the flow of water for the purpose of engine room cooling. This can markedly reduce operational efficiency and may cause marine engines to prematurely wear.

5.2 *General observations*

There was significant variation in the extent and diversity of fouling growth coverage in all sea chests observed. Variation existed between different sea chests on the same ship as well as between ships.

Sea chests devoid of any significant fouling were observed and it was noted that these sea chests had functioning marine growth protection systems running at a setting higher than the manufacturer's recommendation².

More common however were sea chests with medium to high level coverage of fouling organisms. Anecdotal evidence collected from vessel managers indicated in these cases that where there were marine growth protection systems present they were malfunctioning or not performing to a satisfactory level while being run in accordance with the manufacturers recommendations.






Only on one ship were sea chests observed that were fitted with steam blow out tubes. Steam blow out tubes allow the sea chest cavity to be cleared of debris if a blockage occurs affecting the operation of the ship (Taylor et. al. 2002). The sea chests observed that were fitted with steam blow out tubes also had very little biofouling present. It is possible that steam blow out operations may reduce biofouling colonisation.

Sea chest grates were observed to be consistently fouled with dense masses of biofouling, at times up to 90% coverage. In most cases, the fouling had attached to defective paint systems, where paint had delaminated on the angular edges of the sea grate bars.

² Marine growth protection systems work in one of two ways. Either by the release of copper ions via an impressed current into a copper anode located in the sea strainer or the sea chest or by the electrochemical generation of chlorine from seawater with the dosed seawater released into the sea chest.

It is important to note that often vessel managers reported operational difficulties resulting from the extensive fouling of sea chest grates. Any area where biofouling is creating challenge to efficient vessel operation, it is likely that there will be high uptake of management recommendations.

Figure 1: Sea chests and sea chest grates.

			
Figure 1: Steam injection pipe inside sea chest.	Figure 2: Fouled internal surface of sea chest.	Figure 3: Barnacle fouling inside sea chest .	Figure 4: Sea water intakes inside sea chest.
			
Figure 5: Barnacle fouling on sea chest grate.	Figure 6: Fouling coverage significantly blocking grate.	Figure 7: Fouling coverage on sea chest grate.	Figure 8: Sea chest free of fouling - functioning MGPS.

5.3 Recommendation

The internal surfaces of sea chests should be painted with antifouling paints suitable for the flow conditions of seawater through the chest. Care should be taken in application of both anticorrosive and antifouling paint to ensure adequate film build and adhesion to corners and edges.

Where possible, marine growth protection systems should be designed to release dosed water into the sea chest. Care should be taken to ensure that marine growth protection systems are operating at a level that is effective in preventing build up of marine organisms.

If steam blow-out pipes are fitted within sea chests, regular use may minimise growth in the sea chest. External surfaces of the pipes, and holding brackets must be effectively antifouled as they are prone to fouling colonisation.

Sea chest angles and corners should be beveled or radiused to improve antifouling paint adhesion and durability. Sea chest grates should be constructed of round instead of angular bars to similarly improve paint adhesion and durability. Grates should be hinged to enable diver access for in-water inspection and maintenance.

6 Sea Water Inlet Pipes and Overboard Discharges

6.1 Operational relevance

Many vessels have sea water inlets and discharges that connect directly with the ships hull (Taylor et. al. 2002). While there is no sea chest in this case, direct sea water inlets are vulnerable to biofouling colonisation for many similar reasons as sea chests.

The openings of sea water inlets are covered by grates with angular bars and often protrude from the hull slightly with an angular raised rim. As with sea chests designed in this way, angular edges increase surface tension during antifouling paint application and the dry film paint thickness is reduced along these edges, reducing antifouling life and increasing the potential for settlement of marine organisms.

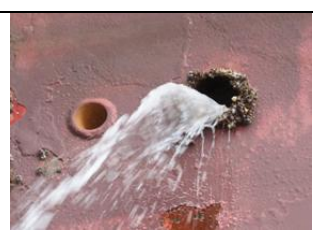
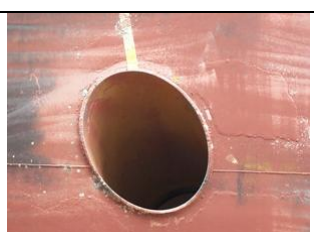





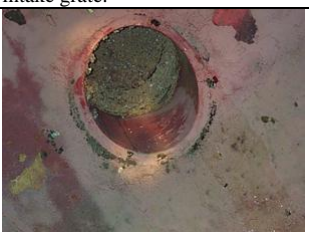
Maintaining clear inlet pipes and overboard discharges that are free of fouling and that allow the free flow of water is critical to ship operation. Blocked inlet pipes that don't allow sufficient flow of seawater can have serious implications for engine cooling, reducing the life of the engine and preventing the ship from optimising efficiency.

6.2 General Observations

High velocity sea water intakes (see cooling scoops 8.3) and heated water overboard discharges, were observed to be free of fouling.

Higher temperatures created as a result of heated water overboard discharges are likely to create conditions where organisms are unable to settle. Where high velocity seawater intakes were present, the vessel (and the hull penetration) was painted with antifouling paint designed for faster ships. In this case, the antifouling paint used on this type of seawater intake has a biocide release rate appropriate for this particular niche area.

Small discharges often had shell growth just inside or around the rim of the discharge pipe. They are generally round in shape, often with ridged hull penetrations and square bars, and like sea chest grates are susceptible to biofouling.

			
Figure 9: Fouling on around ridged hull penetrations.	Figure 10: Heated water discharge point – free of fouling.	Figure 11: Ridged hull penetration.	Figure 12: significant fouling on intake grate.
			
Figure 13: Fouling coverage of 95% on intake grate.	Figure 14: Fouling organisms present inside intake.	Figure 15: heated water discharge point – minimal fouling.	Figure 16: Ridged hull penetration and internal fouling.

6.3 Recommendation

All sea inlet pipes and discharge penetrations should be radiused and grates on sea intakes should be constructed of round bars to improve antifouling paint system adhesion and durability. The paint system should also be applied inside the pipe and accessible internals and the anticorrosive or primer coating selected should be appropriate to the specific pipe material if this material is different to the hull plate.

7 Hull appendages – Unpainted

Unpainted hull appendages are areas that are not painted with antifouling paint for operational purposes. These include such things as anodes, velocity probes and echo sounders.

7.1 *Cathodic protection (CP) anodes*

7.1.1 *Operational Relevance*

Anodes are fitted to the hull to prevent electrolytic corrosion of the hull. There are two basic types of anodes; sacrificial anodes and impressed current anodes (Taylor et. al., 2003).

Sacrificial anodes, generally made of zinc, corrode when electrical currents are generated between the dissimilar metals of the anode and the underwater hull of a vessel. The anodes corrode first and thereby protect the hull (Taylor, 2003). Depending on the degree of corrosion, sacrificial anodes are usually replaced at every docking.

Sacrificial anodes are generally attached to a bracket that is bolted to the hull, leaving a space between the hull surface and the bracket to which the anode is attached.

Sacrificial anodes protrude from the hull surface and, depending on their location along the hull, can create eddies and areas low water flow. Eddies can prematurely deplete the biocide contained within the paint and low flow conditions limits biofouling release rendering the antifouling paint inactive allowing biofouling settlement.

Impressed current anodes are permanent hull fixtures. They continually emit a specific current density for the prevention of hull corrosion and paint de-lamination (Taylor et. al., 2002).

If the impressed current anode is set at a current density that is too high, de-lamination of the hull paint coatings may occur (Taylor et. al., 2002).

Impress current anodes slightly protrude from the hull surface and can create eddies at either end of the anode, prematurely depleting antifouling biocide.

Severe biofouling growth on the surface of anodes can interfere with the water flow over the hull, causing friction and may result in reduced operational efficiency and increased fuel consumption.

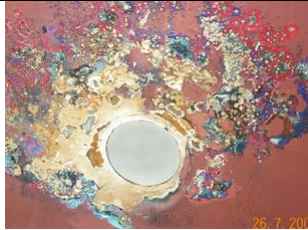






7.1.2 *General Observations*

Very small amounts of biofouling were observed on the eroding surfaces of sacrificial anodes. However, there were fouling organisms observed under and around anodes and it is possible that the mechanism for attaching the sacrificial anodes to the hull creates an area on the hull that is susceptible to biofouling.

The areas of the hull underlying the anode (gap between the hull and the anode) were often found be covered in fouling organisms.

There were a number of impressed current anodes observed. Biofouling on active impress current anodes was minimal and usually confined to either end of the anode, and in areas of paint de-lamination.

Where impressed current sacrificial anodes were inactive, biofouling growth was found to be severe.

			
Figure 17: Impressed current anode – paint coating damage.	Figure 18: Faulty impress current anode significantly fouled.	Figure 19: Functioning sacrificial anode forming zinc salts.	Figure 20: Functioning sacrificial anode. Fouling on bracket.
			
Figure 21: Non functioning sacrificial anode – fouled.	Figure 22: Minimal fouling on hull around impress current anode.	Figure 23: Fouling on trailing edge of impressed current anode.	Figure 24: Close up of fouling on sacrificial anode bracket.

7.1.3 Recommendation

Sacrificial CP and Impressed CP anodes should be inspected in-water and any growth should be removed, ensuring that fouling debris is captured and disposed of to shore facilities.

Anodes should be flush-fitted to the hull. If not flush-fitted, the hull surface under the anode should be stripe coated with a static antifouling to prevent fouling colonization.

If anodes are attached by bolt recessed into the surface the recess should be caulked to remove a potential niche.

7.2 Echo Sounders and Velocity Probes

7.2.1 Operational relevance

Echo sounders and velocity probes or pitot tubes provide information to the bridge on water depth and vessel speed and are usually attached to the vessel bottom. Measurement instruments themselves cannot be painted with antifouling as it may interfere with the performance.

As these areas are unpainted and protrude from the vessels' hull they may be susceptible to biofouling growth.

7.2.2 General observations

There was one echo sounder that was clearly observed during the ship inspections. While there were no whole organisms observed, there were remnants of barnacle settlement.

7.2.3 Recommendation

Unpainted surface and velocity probes should be inspected and cleaned of fouling growth. Fouling debris must be captured and disposed of in an acceptable way on shore. Where retractable pitot tubes are fitted, they should be internally painted with antifouling paint

7.3 Docking Support Strips

7.3.1 Operational relevance

When a ship is in dry dock the hull must be supported. Steel and concrete blocks are arranged in specified locations on the dock floor according to the individual ship's support requirements. The ship takes its position in the dock and as the water is pumped out or the dock is lifted and dried, the ship's weight is supported by the docking blocks.

The docking blocks remain in place throughout the dry dock period. As a result, the areas where the docking support blocks make contact with the keel are not cleaned and painted with antifouling, leaving dull areas or clearly visible docking support strips.

Docking support strips may therefore not be treated with antifouling paint in the required frequency in accordance with the paint manufacturers' specifications, which may make these areas more susceptible to biofouling growth.

Biofouling growth increases hull roughness. Keel roughness caused by biofouling growth along docking support strips may reduce efficiency and increase fuel consumption and wear and tear on the ships' engine.

7.3.2 General observations

Docking support strips were evident on all ships observed. Overall however, these areas were clean and free of fouling.

On only two occasions did there appear to be more biofouling growth on docking support strips than on other areas of the hull. One of these ships had quite obviously suffered significant antifouling paint system failure on the entire hull.

It is clear that good practice in relation to antifouling of docking support strips is already common among the industry.

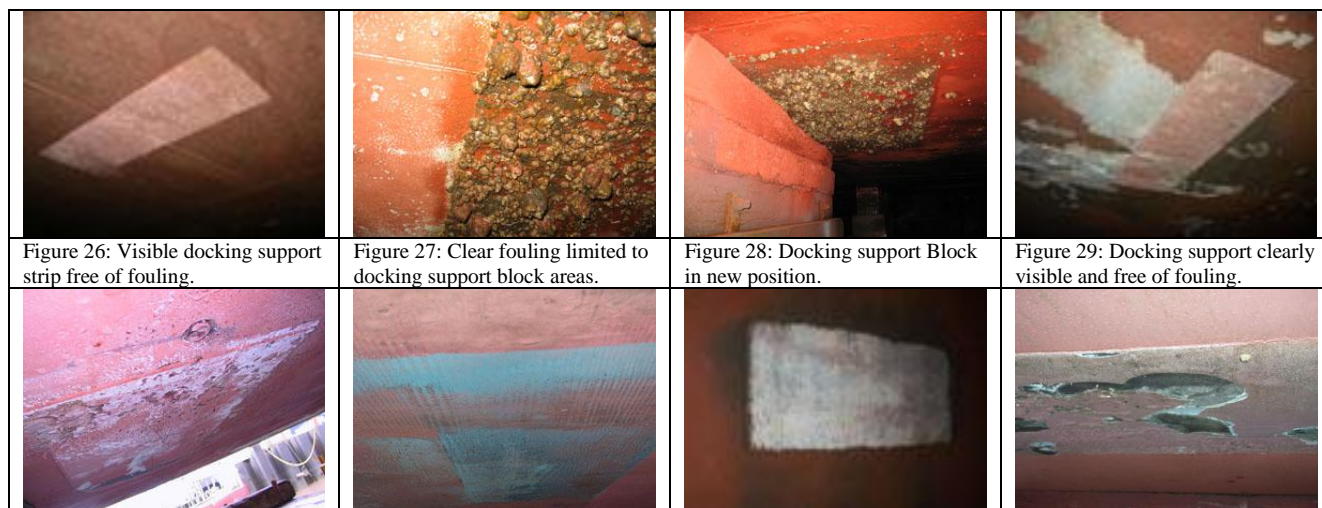


Figure 30: Docking support block requiring antifouling treatment.	Figure 31: Docking support strip visible and free of fouling.	Figure 32: docking support strip clearly visible and free of fouling.	Figure 33: Paint on docking support strip in need of treatment.
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7.3.3 Recommendations

Positions of docking blocks and supports should be varied at each docking to ensure that areas under blocks are painted with antifouling at least at alternate dockings.

7.4 Propeller and Shaft

7.4.1 Operational relevance

Propellers are complex assemblages of fixed and moving parts. The external areas of the propeller assemblages, including the propeller boss, are generally not painted as painting and surface preparation in these areas could damage the seals and sealing surfaces causing oil leakage (Taylor et. al. 2002).

Propeller blades are not generally painted with biocidal antifouling paint as the water turbulence is high and the paint is very quickly polished off.

Propeller blades must be maintained free of fouling to sustain operational efficiency. So much so that it is common practice among the industry to undertake in-water propeller polishing under permit, on an annual basis.

There are many potential niche areas that make up the propeller mechanism including the propeller boss and propeller shaft.

While maintaining clean propeller blades is important to operational efficiency, it is less likely that the propeller boss would be cleaned at the time of propeller polishing, leaving this area more susceptible to biofouling build up over time. Further, as the propeller rotates, the centrifugal force at the propeller hub is less, probably making it easier for biofouling organisms to settle on the propeller hub surface.

When not enclosed, the external surface of the propeller shaft is usually not painted for operational reasons.

The shaft seal assembly, where the propeller joins the stern frame is usually enclosed in a propeller shaft rope guard to protect the area from damage caused by entanglement in rope or fishing net (Taylor et. al., 2002).









The external surfaces of the propeller shaft is painted with antifouling paint, however, this area may be particularly vulnerable to biofouling settlement due to premature erosion of the antifouling paint as a result of high water turbulence and cavitation produced by the propeller.

7.4.2 General observations

Where fouling was observed on propellers, it was predominantly low profile, almost two dimensional forms such as pink encrusting coralline algae, or small newly settled barnacles or tubeworms. However, approximately half the ships observed showed signs of biofouling growth on the propeller hub.

Of particular note was the biofouling growth observed on the external surface of the propeller stems and rope guards. Biofouling in this area was significant on all but one of the vessels observed.

During some inspections there was an opportunity to observe biofouling growth on the internal surfaces of the rope guards and stern seal assemblies. In all cases where this was possible, biofouling organisms were or had been present.

			
Figure 34: Significant barnacle fouling around rope guard.	Figure 35: Fouling around propeller shaft and rope guard.	Figure 36: Fouling patches on propeller hub.	Figure 37: Propeller shaft and propeller free of fouling.
			
Figure 38: Propeller, rudder and stern frame.	Figure 39: Close up of rope guard fouling.	Figure 40: Propeller, rudder and stern frame.	Figure 41: Fouling underneath rope guard.

7.4.3 Recommendation

Propellers should be regularly polished to maintain operational efficiency. Painting propellers with silicone fouling release coatings can maintain efficiency and enable self-cleaning, obviating the need for regular polishing. Unpainted propeller shafts should be cleaned at the same time as the propeller.

Submerged propellers or propulsion units should be routinely inspected for biofouling. If propellers or propulsor units are fouled, in-service arrangements should be made to carry out a safe and environmentally acceptable cleaning.

The externally exposed part of stern seal assemblies and the internal surfaces of rope guards should be carefully painted with antifouling paint.

8 Hull Appendages – Painted

Painted hull appendages are niche areas that, although they are painted with antifouling paint, they may be particularly susceptible to biofouling growth.

8.1 Bow and Stern Thrusters and Retractable Propulsion Units

8.1.1 Operational Relevance

Most modern ships are fitted with thruster units at the bow and/or stern to assist with vessel maneuverability. Bow and stern thrusters are fitted inside round tubes that penetrate the width of the hull. The tubes are usually fitted with grates to prevent large objects from entering the

tube and damaging the propeller. To protect from corrosion, the tubes are most often also fitted with sacrificial anodes (Taylor, et. al., 2002).

Retractable propulsion units are also designed to assist with maneuverability but can be retracted into the hull when not required so as not to interfere with the flow of water over the hull (Taylor, et. al., 2002).

Bow and stern thrusters and thruster tunnels are potentially highly susceptible to biofouling settlement. Thruster tunnels are home to a large number of niche areas including anodes and bolt recesses and grates with angular bars reducing the dry paint film thickness.

These areas also vary between high cavitation and static water flow which can prematurely erode antifouling paint or render it inactive.









8.1.2 General Observations

Most of the ships observed were fitted with bow thrusters, and one retractable propulsion unit was observed.

While the impeller blades were generally clean and free of fouling, where bow thrusters were present, so were biofouling organisms. Often there were signs of paint degradation on the body of the bow thruster and on the internal surfaces of the tunnel, and in some cases an even coverage of biofouling.

Often, in corners where the bars on thruster tunnel grates meet there was a collection of biofouling organisms present indicating a vulnerable area resulting from reduced paint thickness or undermining of the paint coating from an area of coating damage.

Biofouling growth was evident where niche areas were created in nooks and crannies around the bow thruster body and around the cathodic protection anodes attached to the internal surface of the thruster tunnel.

			
Figure 42: Bow thruster and grate – significant fouling coverage.	Figure 43: Fouling attachment in perpendicular angles.	Figure 44: Fouling clusters inside recesses.	Figure 45: Barnacle bases on bow thruster propeller hub.
			
Figure 46: Patchy fouling coverage on bow thruster.	Figure 47: Bow thruster and grate	Figure 48: Sacrificial anodes on internal surface of thruster tunnel.	Figure 49: Patchy fouling on impeller bracket.

8.1.3 Recommendation

The body and area around bow and stern thrusters are prone to paint damage through cavitation forces. High performance systems should be applied to resist cavitation damage and systems routinely maintained at dockings.

The ends of the tunnels where they penetrate the hull should be radiused and grates made of round section to improve paint adhesion and durability.

8.2 Bilge Keels, Cooling Scoops and Propulsion Scoops

8.2.1 Operational relevance

Bilge keels are fitted to reduce vessel rolling (Taylor, et. al., 2002). They extend along most of the length of a vessel and protrude out from the hull approximately 500mm depending on the size of the vessel.

Bilge keels that are not perfectly in line with the flow of water over the hull can cause eddy currents that can prematurely deplete antifouling paint coatings (Taylor, et. al., 2002). As such, bilge keels may be susceptible to biofouling growth. Biofouling growth in this area will increase hull roughness and may impact of vessel operational efficiency.

Cooling scoops are located on the vessel keel and are designed to enable high velocity water intake for steam turbine cooling. They are covered at the point of hull penetration with a grate to prevent the intake of foreign matter (Taylor, et. al., 2002).

Propulsion scoops are similar at the hull interface to cooling scoops but are attached to water jet propulsion units.

While the high water velocity moving into the scoop may prevent organisms from being able to settle, the presence of grates at the point of hull penetration may create a vulnerable niche area if not designed properly.

8.2.2 General Observations

All vessels observed had bilge keels affixed to their hulls, only one vessel had cooling scoops and none were observed that were fitted with jet propulsion scoops.

Fouling was observed on a number of vessels along the outer edge of the bilge keel, on the undersurface along the weld joint between the bilge keel and the hull and areas of paint delamination.

The velocity of water moving through the cooling scoop was likely to be well matched to the polishing and biocide release rate of the antifouling paint. Grates covering cooling scoops created a more vulnerable niche area than the cooling scoop itself. The angles created by the square bars on the intake grate, reduced dry film thickness and the life of the antifouling paint and had biofouling present.

			
Figure 50: Fouling along length of bilge keel edge.	Figure 51: Fouling along bilge keel edge and underside weld joints.	Figure 52: Dense fouling along bilge keel edge.	Figure 53: Algal fouling along bilge keel edge.
			
Figure 54: Bilge keel free of fouling.	Figure 55: Dense fouling along bilge keel edge and hull.	Figure 56: Patchy fouling along bilge keel.	Figure 57: Patchy fouling on paint breakdown areas under bilge keel.

8.2.3 Recommendation

The outer edge of bilge keels and scoops, and the weld joints to the hull should be stripe-coated with additional anti-corrosive and antifouling paint to ensure adequate film build to optimise system durability and antifouling life.

8.3 Rudder Hinges, Rudder Stocks and Stabiliser Fin Apertures

8.3.1 Operational Relevance

There are various types of rudders, all presenting similar challenges in biofouling prevention because of the lack of clearance and construction of the rudders and their carrying assemblies (Taylor et. al. 2003).

The rudder stock secures the rudder in place and creates a narrow hinge space between the rudder and rudder stock. Situated aft of the propeller, the rudder is exposed to a large amount of water turbulence and cavitation which can prematurely polish the antifouling paint and remove it from the rudder surface, leaving the area exposed to biofouling.









Stabiliser fins protrude at perpendicular angles from the vessels' hull are most often retractable and are fitted to ferries and cruise ships to minimise roll. Stabiliser fins are hinged at the trailing edge to control vessel lift.

Hinges on rudders and stabilizer fins are exposed to variations in water turbulence and require special care in painting to prevent biofouling attachment.

8.3.2 General observations

One vessel with stabilizer fins attached was observed. There was evidence on the dock floor that a large number of biofouling organisms, mainly barnacles had been removed.

All rudders observed fouled to some degree. Fouling was concentrated mainly in the rudder stock, rudder hinge area and along the rudder trailing edge.

			
Figure 58: Fouling in rudder hinge area.	Figure 59: Fouling coverage on rudder stock.	Figure 60: Patchy fouling on trailing edge of rudder.	Figure 61: Starboard side stabiliser fin..
			
Figure 62: Fouling on rudder.	Figure 63: Fouling within rudder hinge	Figure 64: Rudder, propeller fouling.	Figure 65: Propeller and rudder - high cavitation area.

8.3.3 Recommendation

Recesses within rudder hinges and behind stabilizer fins need to be carefully and effectively cleaned and re-antifouled at maintenance dockings. These niches should be inspected between dockings and fouling removed, ensuring that debris is captured and disposed of appropriately on land.

Rudders should be moved port and starboard during the painting process to ensure that all surfaces are correctly painted to the correct specification of the antifouling system.

9 Propeller Polishing and In-Water Cleaning

While biofouling in niche areas can be managed and significantly reduced by better surface preparation, careful antifouling paint application in line with the manufacturers recommendations, and the application of different products to different areas, it is likely that some biofouling will always occur.

In these cases, it is recommended that careful in water removal of organisms from the niche areas when they occur will reduce the risk that they may be translocated from one area to another.

Many vessel operators routinely conduct propeller polishing to improve ship performance. This practice may also minimise the risk of species translocation as propeller polishing provides an opportunity to inspect fouling prone niches and remove significant growth. Areas that should be inspected by divers undertaking propeller polishing include:

- Rudder stock and hinge
- Stabiliser fin apertures
- Rope guards and propeller shafts
- Cathodic protection anodes
- Sea chest and bow thruster tunnel grates
- Overboard discharge outlets and seawater inlets

While undertaking in water inspections, care should be taken to ensure that any growth removed is captured and disposed of on shore not to allow it to re enter the water.

9.1 Review of the ANZECC Code of Practice

The current ANZECC Code of Practice prohibits all in-water cleaning without a permit. It is a recommendation of the Commercial Vessels Biofouling Project that the code be reviewed.

While the above preventative mechanisms are likely to considerably reduce the incidence and degree of biofouling growth in niche areas, there will always be some amount of biofouling present and the many variables involved in antifouling paint application, mean that from time to time system failure may occur.

In these instances, encouraging the removal of mature organisms where the organisms are captured and disposed of on shore should form one part of a comprehensive strategy for fouling prevention and a proactive means of reducing the risk of organism translocation.

10 Assessment of Guidelines and Monitoring Uptake

The recommendations of this project have been developed into Guidelines for the Prevention of Biofouling on Commercial Vessels (Annex I). It is intended that the guidelines be distributed among ship owners and operators and dry dock managers and communications activities will be undertaken as part of the National System Communications Plan.

Testing of the methods recommended in the guidelines should be undertaken in the short to medium term and monitoring of industry uptake should be undertaken in the medium to long term following the initiation of the shipping industry aspect of the National System Communication Plan.

The following activities are recommended to monitor the level of industry uptake of the guidelines:

- Ongoing and discrete monitoring of ships going to dry dock over time and collection of information relating to the biofouling prevention methods used.
- Following the recommended review of the ANZECC Code of Practice for In –Water Cleaning, propeller polishing permits may be monitored to assess the frequency of additional niche area biofouling removal activities.

11 References

Lewis, J. A (2002) The significance of the prospective ban on tributyl tin in antifouling paints in the introduction and translocation of marine pests in Australia. Report prepared for Agriculture Fisheries and Forestry.

Taylor, A.H & Rigby, G. (2002) The Identification and Management of Vessel Biofouling Areas as Pathways for the Introduction of Unwanted Marine Organisms. Report prepared for Agriculture Fisheries and Forestry.